REMARKS

We acknowledge the Examiner's indication that claims 5, 8, 9, 28, 31, and 32 would be allowable if amended to be independent form and to include all of the limitations recited in base and intervening claims. We submit, however, that the applicants are entitled to greater protection of subject matter than that covered by these claims.

We have amended independent claims 1, 24, and 47 to recite that first data that has been derived from body while bearing a guided wave, produced in response to application of a first excitation signal to the body, and a second excitation signal.

Prior Art Rejections

Giurgiutiu

The Examiner rejected independent claims 1, 24, and 47 as anticipated by Giurgiutiu. We submit however that Giurgiutiu neither discloses nor suggests first data that has been derived from body while bearing a guided wave, produced in response to application of a first excitation signal to the body, and a second excitation signal, as recited in independent claims 1, 24, and 47.

It is well known within the art that propagating ultrasonic/elastic waves are attenuated and slowed down due to either structural boundaries and/or damage. However, it is also known that a change of temperature will adversely effect the amplitude of the propagating wave. Still further, any change in speed of the propagating guided wave due to small damage such as, for example, fatigue cracks in metallic structures, is marginal and difficult to detect.

Applicant's invention includes a second excitation signal, which advantageously can be used to modulate the damage contained within the body. The modulation of that damage, in turn, modulates the propagating guided wave. The modulation of the propagating guided wave can be detected or established using the instantaneous phase/frequency of that wave, which is independent of environmental characteristics that affect the cited prior art.

In certain embodiments, by using the second excitation signal the phase characteristics of the modulated propagating guided wave can be used to reliably detect damage.

Referring to the prior art, the Giurgiutiu reference can be summarized as follows:

(a) bond to piezoceramic sensors on a structure to be monitored;

(b) measure the impedance of the piezoceramic sensors, that is any change of impedance will provide an indication of damage;

(c) propagate lamb waves in the structure such that any change in lamb waves will provide an indication of damage; and

(d) analyze various signal characteristics in order to detect that damage, that is, use amplitude, phase, reflection, time of flight view reflections etc to identify the presence of damage.

The application of lamb waves for damage detection is well known within the art and has been published in many papers. However, it will be appreciated that there is no similarity between the impedance-base method of Giurgiutiu reference and the embodiments of the present invention. While Giurgiutiu needs two embedded sensors within the body to propagate lamb waves, these sensors do not provide an additional excitation to detect damage. One skilled in the art readily appreciates that the principles of damage detection in Giurgiutiu as compared to the embodiments of the present invention are very different. Giurgiutiu is based on the well-known characteristic that ultrasonic/elastic waves exhibit reflections due to structural boundaries such as, for example, rivets, joints, stiffeners, as well as damage. A major problem that Giurgiutiu attempts to surmount is a detection of damage using such reflections. However, one skilled in the art will also appreciate that the embodiments disclosed in Giurgiutiu will also be adversely effected by changes in temperature. Still further, one skilled in the art also appreciates that it will not be possible to detect relatively small damage such as, for example, fatigue cracks in metallic structures when using the embodiments described by Giurgiutiu. These problems can be surmounted by, as mentioned above, analyzing the phase characteristics of a guided wave propagating within the body to be monitored in the presence of a second excitation signal.

In preferred embodiments, the second excitation signal is a relatively low frequency signal as compared to the first excitation signal.

It is suggested that Giurgiutiu does not contain any technical motivation for introducing the use of a second excitation signal with the intention of producing detectable modulation of the

propagating guided wave since Giurgiutiu purports to provide a complete solution to damage detection using lamb wave. There is no hint within Giurgiutiu patent as to how one might use such an additional or further excitation signal.

It is suggested that independent claims 1, 24, and 47, as amended, are clearly patentable over the Giurgiutiu reference.

We further submit that because claims 10-17, 20 and 21 depend from independent claim 1; claims 33-40, 43, and 44 depend from independent claim 24; and claim 48 depends from independent claim 47, these dependent claims are patentable for at least the same reasons that claims 1, 24, and 47 are patentable.

Giurgiutiu in view of Bechhoefer

The Examiner also rejected dependent claims 2-4, 22, and 25-27 as unpatentable over Giurgiutiu in view of Bechhoefer. Bechhoefer was cited as disclosing calculating a phase modulation of first data using $\phi(t) = \arctan\frac{\hat{x}(t)}{x(t)}$, where $\hat{x}(t)$ is the Hilbert transform of the signal represented by the first data and x(t) is the signal represented by the first data.

The Bechhoefer patent describes a method of fault detection in rotating machinery. It can be appreciated, firstly, that the method disclosed in Bechhoefer patent is related to vibration analysis and not to guided wave propagation. Secondly, it is related to fault detection in rotating machinery and not to structural damage detection. This type of work is extremely well known and is based on the well-known phenomena of rotating machinery. Impact type faults in rotating machinery such as, for example, local tooth faults in gear boxes and ball-bearings, result in impulse excitation. This modulates the rotational vibration of machines. It is now a standard procedure to record such vibration signals using accelerometers located at the various positions. These signals are then analyzed for modulations related to various frequency ranges.

Again, it can be appreciated, that there are many limitations contained within the amended claims that do not appear in, and are not obvious from the Bechhoefer patent. There is no motivation within Bechhoefer patent for using guided waves. Still further there is no motivation for detecting the presence of modulation of a guided wave that has been brought

about by a combination of a structure defect within a body to be monitored and a further excitation signal being applied to that body while a guided wave is propagating.

The Examiner has asserted that it will be obvious to "modified Giurgiutiu patent to include calculating a phase modulation with the first data using ....". However, one skilled in the art readily appreciates that the combination of Giurgiutiu patent and Bechhoefer patent is meaningless as they are based upon distinctly different principles. As indicated above Giurgiutiu patent is based upon guided waves whereas Bechhoefer patent is based upon vibrations which are not guided waves. One skilled in the art appreciates that the term "guided wave" has a very specific technical meaning. That specific technical meaning is such that it does not encompass mere vibrations.

It is respectfully requested that the Examiner reconsiders his assertion of lack of inventiveness in light of the above since combining the teaching of the Giurgiutiu patent with the teaching of the Bechhoefer patent has no technical meaning.

Giurgiutiu in view of Lichtenwalner

The Examiner also rejected dependent claims 6, 7, 29, 30 and 45 as unpatentable over Giurgiutiu in view of Lichtenwalner. Referring to the Lichtenwalner's patent, it can be appreciated that Lichtenwalner's patent discloses a damage detection method that is based upon broadband excitation of piezoelectric transducers. It is clear to one skilled in the art that Lichtenwalner's patent is not based, at all, on the principle of using guided waves. The term guided wave does not appear at all within Lichtenwalner's patent. Indeed, one skilled in the art appreciates that broadband excitation will never lead to generation of guided waves within a body. One skilled in the art also appreciates that the difference in phase and amplitude described in the patent at column 4, lines 25 to 67, column 7, lines 25 to 40 and column 11, lines 34 to 42 and in the examination report at point 5, pages 4 to 5, are related to characteristics of the determined transfer functions rather than to the instantaneous phase and amplitude, that is, the modulation, of any propagating guided waves. Again, as with Bechhoefer patent above, this citation is not related at all to the principles that are based upon the use of guided waves which

have been modulated by the presence of damage within the structure and a further excitation signal.

Giurgiutiu in view of Rose

The Examiner also rejected dependent claims 18, 19, 41 and 42 as unpatentable over Giurgiutiu in view of Rose. It can be appreciated that the embodiments disclosed in Rose are based on classical guided ultrasonic waves. Rose's patent is similar to the Giurgiutiu reference. The physics is similar. However, the methodology and signal processing involved are very different. Rose uses two ultrasonic waves. Each wave is either a swept sine envelope excitation or an impulse excitation. Damage is detected by noting any change in the spectrum of a response signals. Successive response signals are compared to identify any such change. While the embodiments disclosed in Rose appear to use guided waves, they do not exploit the modulation of the propagating guided wave that results from a combination of damage within the body and a second excitation signal being applied to that body and, in particular, they do not exploit the phase characteristics of the propagating guided wave to detect any such damage.

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Respectfully submitted,

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